FAULT-CONTROLLED FLUID SEEP POTENTIAL AND SURFACE STRENGTH AT THE ISIDIS & ELYSIUM PLANITIA MER SITES BASED ON NUMERICAL MODELING OF WRINKLE RIDGE TOPOGRAPHY. C. H. Okubo[1], R. A. Schultz[1], and K. L. Tanaka[2]; [1]Geomechanics-Rock Fracture Group, Department of Geological Sciences/172, University of Nevada, Reno, NV, 89557-0138. [1]chriso@mines.unr.edu; [2]Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ, 86001.

Introduction: We utilize topographic inversion models of MOLA-based wrinkle ridge topography to evaluate crustal strength and to predict locations of potential fracture-controlled fluid seeps at Mars Exploration Rover (MER) sites in Isidis and Elysium Planitia.

Methods: Numerical models of material displacements around slipped faults are commonly used to determine fault geometries within fault-related folds. In the topographic inversion method, model fault geometries are iteratively varied until a model surface is produced that best-fits observed coseismic surface displacements [1,2] or topography [3,4].

In this abstract, a boundary element model [5] is used to predict the fault geometries below wrinkle ridges at the Isidis (Fig. 1A) and "Elysium" (site is actually in Utopia Planitia) (Fig. 1B & 1C) sites using the topographic inversion method. Also, mechanically weak horizons are inferred at the intersections of backthrust faults and primary thrust faults. This is because the nucleation of backthrusts is predicted when a primary thrust fault propagates through a mechanically weak horizon [6,7]. Backthrusts are not predicted to form in the absence of mechanically weak horizons [7]. Such horizons are consistent with bedding plane interfaces, as well as changes in rock strength, clast angularity, and induration, and thus can signify changes in lithology.

The best-fit model thrust fault geometry is used to predict the frictional strength profile of the crust at each wrinkle ridge based on optimum failure plane orientations for frictionally slipping faults. Material displacements corresponding with the best-fit surface yields the magnitudes and directions of crustal strain due to fault slip. The corresponding (plane) strains are used to evaluate the tendency for nucleation of small-scale normal faults, thrust faults, and joints. Predicted locations of these small-scale fractures, as well as surface exposures of the model faults, are then registered with ridge topography and MER landing ellipses.

Results & Implications: Our numerical models show that the topography of a prominent wrinkle ridge at Elysium is consistent with displacements around a subjacent primary thrust and a backthrust fault that intersect at 2 km depth. We interpret this intersection as evidence of a mechanical discontinuity, possibly the contact between younger Hesperian ridged plains material (Hr) and older undivided Hesperian-Noachian material (HNu) or some other well-defined, localized interface. In contrast, the ridges at Isidis show no topographic evidence of backthrusts, and therefore no evidence of mechanical discontinuities within the crust.

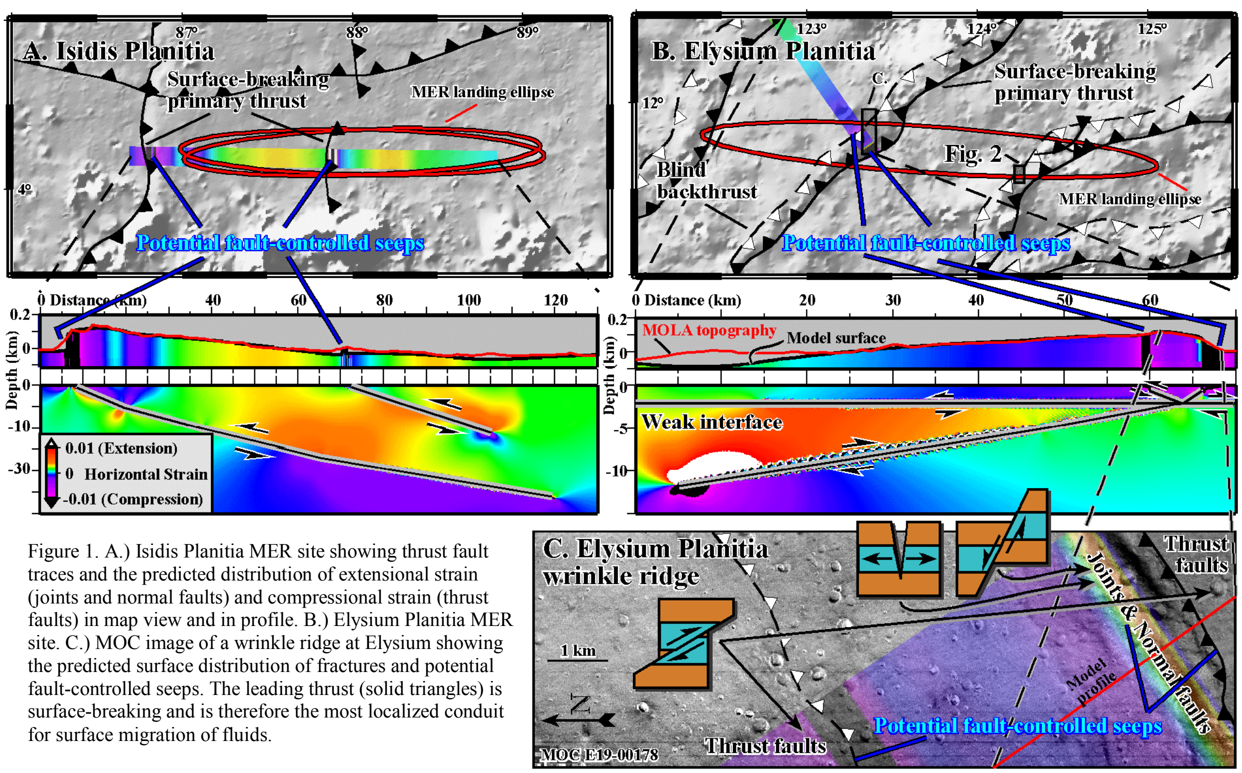

Figure 1. A.) Isidis Planitia MER site showing thrust fault traces and the predicted distribution of extensional strain (joints and normal faults) and compressional strain (thrust faults) in map view and in profile. B.) Elysium Planitia MER site. C.) MOC image of a wrinkle ridge at Elysium showing the predicted surface distribution of fractures and potential fault-controlled seeps. The leading thrust (solid triangles) is surface-breaking and is therefore the most localized conduit for surface migration of fluids.

This suggests that either the contact between the highland basement rock (Nplh) and the basin-filling material (Hvr) is gradational or that both units have comparable strength and that other potential mechanical discontinuities are absent. (Geologic units of [8].)

Characterization of near-surface materials. We evaluate the frictional strength of the crust at both MER sites by examining the dip angles of the best-fit model faults. Values of frictional strength are used to interpret the character and origin of the deposits at each site. In granular soils and poorly indurated sedimentary sequences, frictional strength depends on the particle size distribution (sorting), packing (porosity), and particle shape. Friction is less than that of rock and rock masses for rounded particles, higher porosity, and uniform particle size. Materials composed of angular particles can be as strong as indurated rock masses regardless of particle size and sorting [9]. As a result, the formation and transport mechanisms exert a significant control on the strength and deformability of these deposits.

Model fault dips within Isidis range from 10° to 22°, corresponding to friction coefficients of 2.75–1.04. Friction coefficients >1 are consistent with pervasively fractured rock masses. These values, along with the absence of a mechanical discontinuity, suggest that the crust is mechanically homogeneous to a depth of 30 km. This implies that the basin filling deposits (Hvr) are as strong as the underlying and surrounding basement rocks (Nplh). Therefore individual clasts within the basin filling Hvr are most likely angular. High angularity is consistent with locally derived deposits, undergone minimal transport and rounding. Therefore the lack of a well-defined mechanical interface, as well as the potential angularity of the constituent clasts suggests that Hvr may be colluvium derived from local highland rocks (Nplh). This origin supports previous interpretations of Hvr that are based on photogeologic evidence [8]. Further, smooth plains material (Apr), which covers the Nplh-Hvr contact in [8], is not observed in THEMIS images and thus does not produce an interface.

At Elysium, faults above the 2 km discontinuity have dip angles between 31°–75°, while below 2 km the faults dip at 9° & 10°. These angles correspond to coefficients of friction of 0.53–0.84 for the material above 2 km and friction coefficients of 3.08–2.75 for material below 2 km. Thus, the near-surface basin filling deposits at Elysium (Hr) are frictionally weaker than the basement rock (Npld). If these materials are derived from the adjacent highland rocks (Npld), the constituent clasts would require a greater degree of rounding consistent with extensive transport or reworking than at Isidis. Alternatively, Hr may consist of extensive lava flows [8]. The model-predicted friction coefficients of this upper layer are in fact consistent with friction coefficients for lava flow rock masses of Hawaiian shield volcanoes, which range between 0.3 and 0.6.

Near-surface ground-water. Faults act to direct fluid flow, as either conduits [10,11] or as barriers [12,13]. Further, slip along faults generates substantial heat [14, 15], which may act to melt permafrost within adjacent wall rock. Consequently, surface-breaking faults are potential locales of fluid discharge and are important areas to look for evidence of past fault-related fluids [16] or fluid seeps.

Our models show that the primary thrust faults below the wrinkle ridges at Isidis and at Elysium are surface-breaking. These faults breach the surface within shallow fault-related fold anticlines in front of the ridges. These depressions may act as structural traps to localize fluids and associated sediments and clays. Furthermore, model strain distributions predict localization of horizontal extensional strain within the hinges of the ridges and localized horizontal compression within 5 km of the ridge crests. This suggests vertical jointing and small-scale normal faulting along ridge crests and small-scale thrust faulting along ridge flanks, making these areas potential zones of fracture-controlled fluid seeps. Additionally at Elysium, a backthrust is predicted, but the upper tip does not break the surface. Fluids migrating along the backthrust will encounter a zone of small-scale fracturing within the fold above the upper backthrust tip. The surface expression of these fluids would be diffuse. Since fluid flow localizes around faults, we predict that at both Isidis and at Elysium, the most potentially productive locales to search for fluid seeps or evidence of past fault-related fluids are along the scarps of the surface-breaking thrust faults. A possible example of a fluid seep associated with a wrinkle ridge occurs 60 km east of the ridge in Fig. 1B (Fig. 2).

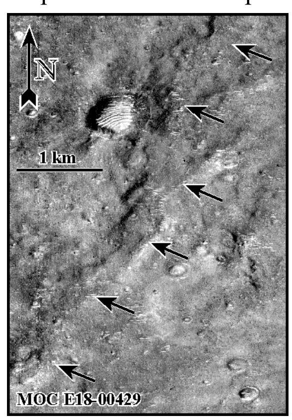

Figure 2. Sinuous channel (arrows) along the flank of a wrinkle ridge. Channel may originate at or near a ridge crenulation produced by a surface-breaking thrust fault.

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